A New Approach of Detection and Recognition for Artificial Landmarks from Noisy Acoustic Images

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Abstract. This paper presents a framework for underwater object detection and recognition using acoustic image from an imaging sonar. It is difficult to get a stable acoustic image from any type object because of characteristic of ultrasonic wave. To overcome the difficulties, the framework consists of the selection of candidate, the recognition, and tracking of identified object. In selection of candidate phase, we select candidate as possible objects using an initial image processing and get rid of noise or discontinuous object using a probability based method in series of images. The selected candidate is processed in adaptive local image processing and recognition using shape matrix recognition method. Identified object in previous phase is tracked without selection of candidate, and recognition phase. We perform two simple tests for the verification of each phase and whole framework operability.

Keywords: Underwater recognition framework, Imaging sonar, artificial landmark.

1 Introduction

In recent years, object recognition and position estimation using image processing have been researched in underwater robot fields. Although an optical camera is used for underwater image processing, it has a number of problems such as light, turgidity, floaters, electric power, etc. For this reason, an imaging sonar is employed by many researchers [1][2][3].

Imaging sonar is used to measure the direction and intensity of the echoes against the object. Unfortunately, the imaging sonar suffered from the characteristics of ultrasonic wave, acoustic image coordinate, and underwater condition even when a known target object is used [4][5]. These make it is difficult to detect and to recognize objects using imaging sonar in underwater environment. This paper proposes a framework for reliable object detection and recognition to cope with the defects of the imaging sonar.

1.1 Framework

The proposed method is expanded from our previous research [6]. A framework for object detection and recognition was proposed and a simple test was performed.

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In this paper, we expand the algorithm to apply to the multi object detection and recognition. Fig.1 shows a proposed framework for the object detection and recognition in underwater environment. In the proposed method, we present a multiple selection of candidate and filtering method with in series of images for the multi object detection.

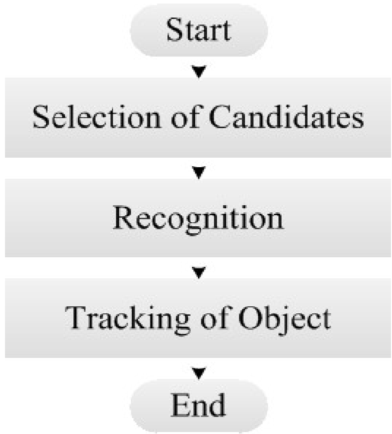


Fig. 1. A framework of detection and recognition method

1.2 Artificial Landmark

The proposed method uses artificial objects as target objects. Natural objects in underwater environment have non-fixed and complex shapes, which make it difficult to recognize them. Furthermore, the characteristics of the acoustic image are very unstable due to a speckle like a salt noise and unstable intensity in the same region [4]. For this, we develop an artificial landmark which is considering the characteristics of ultrasonic waves and imaging sonar [2], and the artificial landmark is used to verify the proposed object recognition algorithm.

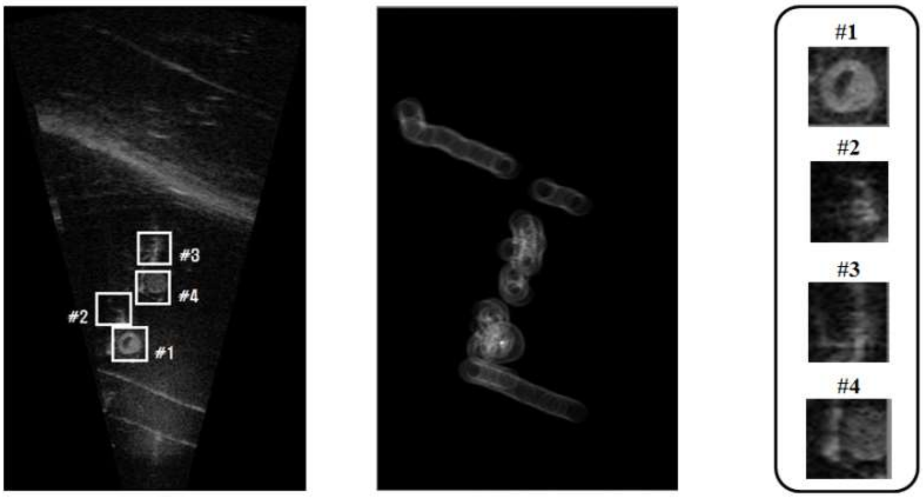
2 Object Detection and Recognition Method

As shown in Figure 1, the proposed object recognition framework consists of three parts, which are the selection of candidates of target objects, the recognition of filtered candidates, and tracking of identified objects. The selection of candidates is specifically divided into two steps. First, we try to find likelihood candidates of objects from whole image. Then, a probability based method similar to particle filter is applied to filter out fake candidates in series of images. This makes a chance to use more efficient, forceful noise filtering. The filtered candidates are processed by local image processing in a small region, and then we use the shape matrix method to identify candidate's ID. After a target object is recognized, it is tracked by mean-shift tracking algorithms without performing the candidate selection and recognition procedures.

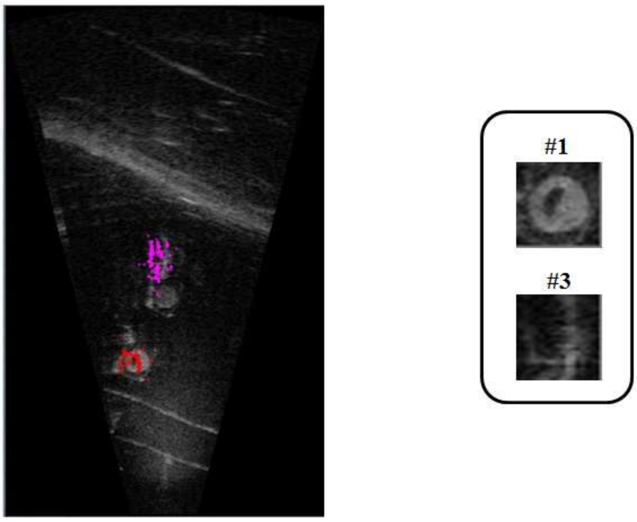
2.1 Selection of Multiple Likelihood Candidates

As mentioned, the proposed method used artificial landmarks as target objects. The candidates are obtained from the whole image according to the used landmark model. The used landmarks have circular shape with various inner fan shapes. Therefore, the likelihood candidates which could be matched with target objects are acquired as circular shapes in the image.

For the selection of likelihood candidates, a matching map is needed. It is calculated by comparing the landmark model and the extracted edge image using Hough circle transform (Fig.2-b). The matching map represents a probability that target



(a) Original image (b) Matching map (c) Likelihood candidates



(d) Filtering candidates (e) Result (Selected Candidates)

Fig. 2. Process of selection of candidates

objects would be exist in the received acoustic image. The regions which have high probability in the matching map is considered as likelihood candidates (Fig.2-c). At most 5 regions are extracted as likelihood candidates from each image. . If all matching values are smaller than the number of edge pixels of landmark model, we decide that any target object does not exist in the current image.

An outer model of artificial landmark is calculated by the following equations. (1) is a distortion equation due to pitch (downward) of imaging sonar. (2) is a scale equation which consider the image scale from the range of the field of view (FOV). An outline of a landmark at X and Y axis is (x_{circle}, y_{circle}), and a distorted outline related to pitch angle is ($x_{distort}$, $y_{distort}$), where the unit is metric. An outer model of artificial landmark in image plane is (x_{img}, y_{img}), where unit is pixel. The imaging sonar's pitch and range of FOV are θ_D and *window_length*, respectively.

$$\begin{bmatrix} x_{distort} \\ y_{distort} \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & \cos(\theta_D) \end{bmatrix} \begin{bmatrix} x_{circle} \\ y_{circle} \end{bmatrix} \tag{1}$$

$$\begin{bmatrix} x_{img} \\ y_{img} \end{bmatrix} = \begin{bmatrix} 1/(window\_length/512) & 0 \\ 0 & 1/(window\_length/512) \end{bmatrix} \begin{bmatrix} x_{distort} \\ y_{distort} \end{bmatrix} \tag{2}$$

2.2 Filtering of Likelihood Candidates

To decrease a ratio of fake detection in noisy images, a probability based method similar to particle filter is applied to find out fake candidates in series of images. First, 1000 to 2000 particles are randomly scattered around the position of each likelihood candidate, and it is designated as a particle group (Fig.2-d). Then, the belief of each particle is updated by using consecutive images. Like the selection of likelihood candidate, extracted edge image and landmark model are used to calculate the belief.

All particle groups are considered three conditions because it may be noise or disappeared. The first, if a standard deviation of particle group is larger than 25% of size of outer model for five times, we decide that the likelihood candidate is not object. Second, it is the agglomeration of particle groups. The particles could be possible to detect the same likelihood candidate. In this case, we should be forced to delete particle groups except one. Third, if recognition of candidate is failed sequentially, we delete its particle group. This is processed when the object is disappeared in image. Filtered particle groups or likelihood candidates are to be the result of selection of candidates phase. A mean position of particle group is offered to recognition phase.

2.3 Recognition of Filtered Candidates

As a recognition phase, multiple trials for recognition allow using various pre-processing filters just for a small region of each likelihood candidate where pre-processing filters are prepared in case study in advance. Fig.3 is an example of pre-processing filter which is adapted in this research. The input image is filtered by the median and the bilateral filter. And then, filtered image is to be black-white image by otsu-thresholding method.

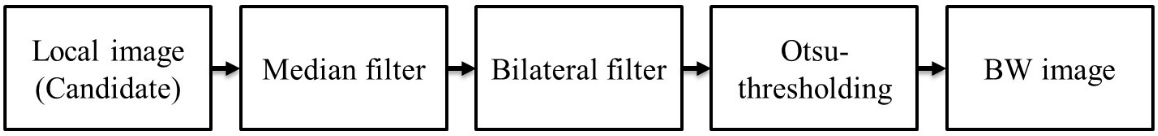


Fig. 3. Process of pre-processing filter

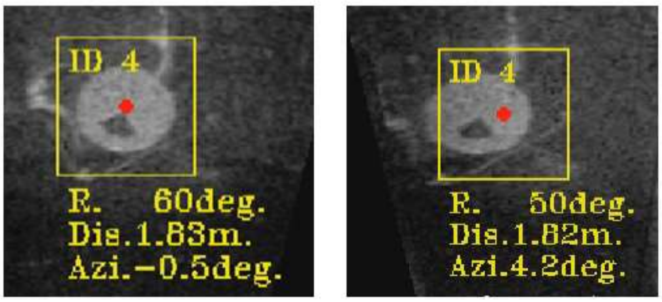
After each pre-processing, we use the shape matrix method for recognition. The artificial landmarks have an I.D separately. First, calculate a shape matrix at the candidate position in the image plane, then calculate a similarity between the given shape matrix of each landmark and obtained shape matrix [5]. If a value of similarity after pre-processing is over certain threshold, the candidate gets I.D. A matching function between shape matrix A (known) and B (obtained) is (3).

$$M(A,B) = 1 - \frac{1}{m \times n} \sum_{j=1}^{n} \sum_{i=1}^{m} \left| A_{ij} - B_{ij} \right| \tag{3}$$

2.4 Tracking of Identified Object

The identified objects (or landmark) are tracked without selection of candidates and recognition in series of images. The object tracking is achieved by general mean shift tracking method [8]. Instead of using Hue image, the proposed method performed mean shift tracking using intensity image because the imaging sonar provides only one channel image.

As shown in Fig.4, it shows the result of the tracking. Each tracking result indicates the target object properly, but it does not indicate on the center of object in Fig.4-b. This reason is the lack of the information which is one channel and unstable image.

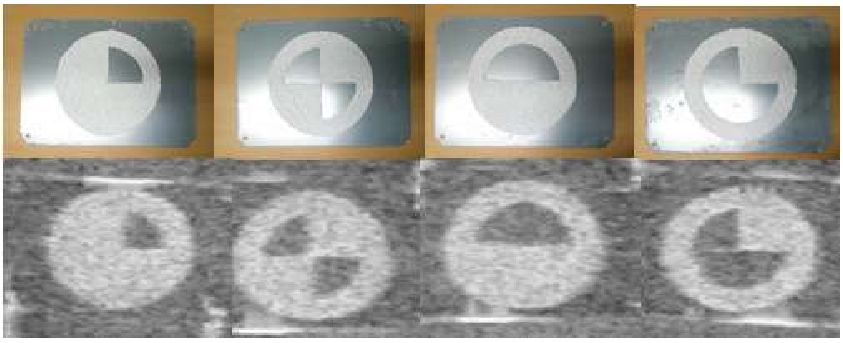


(a) Correct (b) Incorrect

Fig. 4. Result of mean-shift tracking in single object

3 Experiment

To verify the proposed object recognition framework, an experiment was performed in a pool, and four artificial landmarks which have distinctive I.D. are used as target objects (Fig. 5).



(a) I.D 1 (b) I.D 2 (c) I.D 3 (d) I.D 4

Fig. 5. An artificial landmarks

3.1 Multiple Object Detection and Recognition in Sequential Image

The first experiment was carried out to verify the performance of the object detection and recognition when the multiple objects appeared in successive images. In this experiment, only target objects were located in the pool.

The experimental result is shown in Fig.6. At the first image, ID.2 was recognized at the center of the image successfully. During tracking the recognized object (ID.2), another object appeared from upper right side of the subsequent images. Then, the new object was recognized as the landmark ID.3. At the last image, both the landmarks ID.2, and ID.3 are identified and tracked at the same time. It is verified that the object is not selected the same candidate repeatedly.

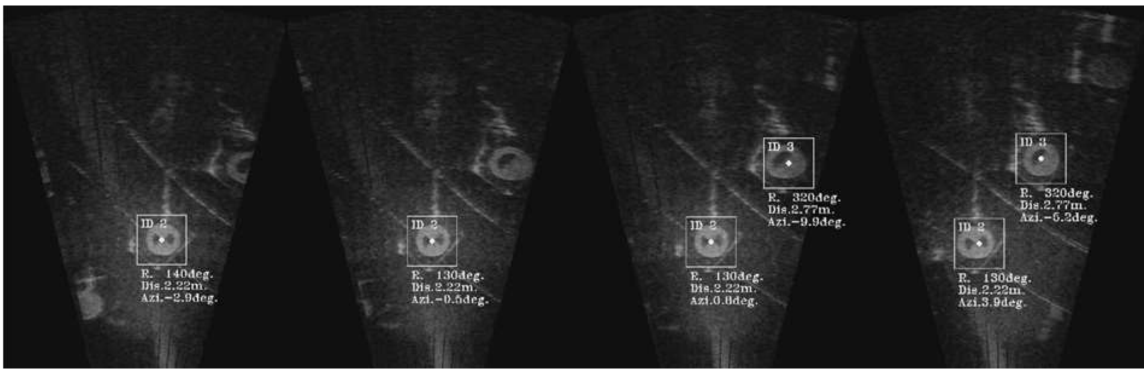


Fig. 6. Multiple object detection and recognition

3.2 Robust Object Detection and Recognition in Multi-shape Object

The second experiment was performed to verify the proposed method when unknown objects were present. The proposed algorithm is designed to detect circular shape of objects because the developed artificial landmark has a circle shape. So, we performed a test about the robustness of the detection algorithm in the presence of various shapes of objects in the pool.

Fig.7 shows that the various objects move from right to left in sequential images. The shapes of objects are star, rectangle, grid, etc. As a result, probability based filtering method worked well. All the unknown types of shapes except circle were filtered out. Even though some objects were not filtered out in the selection of candidates, it could be deleted in the recognition phase because of the similarity test of shape matrix.

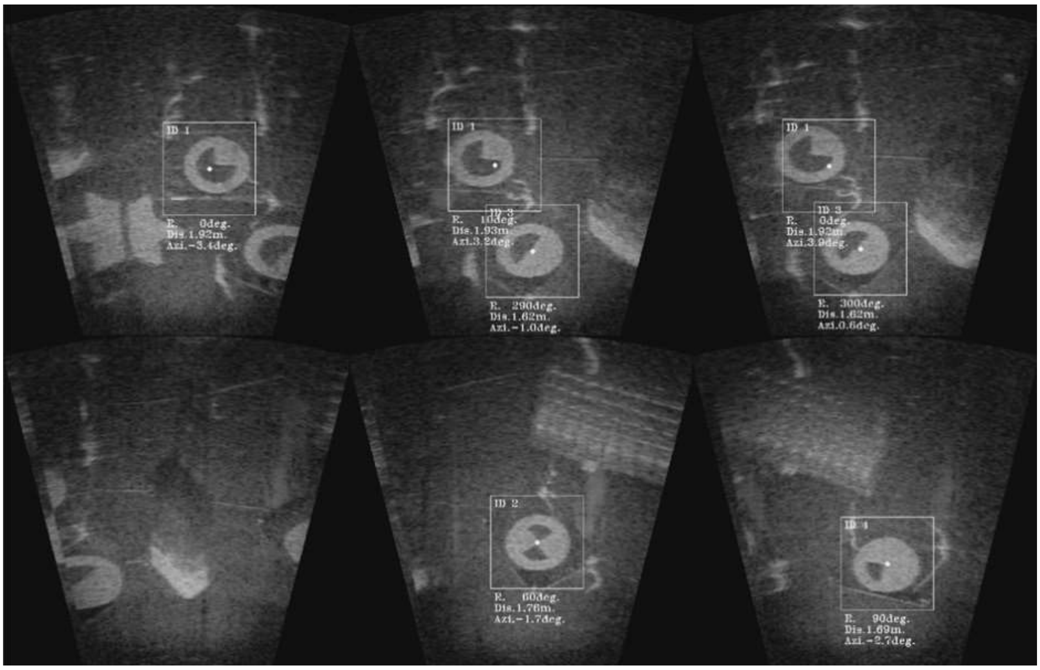


Fig. 7. Robust recognition in multi-shape object

4 Conclusion

This paper proposed the framework for underwater object recognition using imaging sonar. The acoustic image received from imaging sonar is unstable due to ultrasonic waves. So, it is difficult to detect and to recognize target objects. To solve this problem, we selected a number of likelihood candidates as high-score similarity object using Hough circle transform. Then, false likelihood candidates were filtered out by the probability based filtering method before recognition phase. The selected candidates after filtering process were used to recognize the target objects using shape matrix method. An identified object was tracked by the mean shift method. Using these processes, the proposed method can provide a reliable detection and recognition using imaging sonar in underwater environment.

We performed two simple tests in the pool for the verification the proposed method. As a future direction, we plan to run the proposed method in real-time and perform experiments in a real sea environment. And, we will try to extend proposed framework to recognize natural objects in the near future.

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